1898MNRAS..58..488D

The Great Red Spot on Jupiter. By W. F. Denning.

In *Nature* for 1898 August 4 I made some general comments on the associations and rate of motion of this remarkably durable object. Having been further examining the evidence bearing on the early history of the spot, it may be interesting to refer to some of the descriptions of this object in and since 1869, and then to give a table of the varying rotation period it has exhibited during 29 years. I have grouped the observations into periods of about three years, and have selected what appeared to be the most accurate. Though the times of transit had, in several cases, to be estimated from sketches they are believed to be fairly good, as they were carefully checked by other observations made at nearly the same period. Everything lends countenance to the view that the large brick-red spot detected by Russell, Pritchett, and Dennett in 1878 July, and by Tempel, Niesten, and others in the following month, was identical with the object described and figured by Gledhill in 1869 November 14 to 1870 March 29, and on 1871 December 1; by Mayer in 1870 January 5; by Knobel, Birmingham, Pratt, Terby, and Browning in the early months of 1872; by Lord Rosse and Dr. Copeland, 1872 December 31 to 1873 April 10; by Russell and Bredichin in the summer of 1876; and by other observers at various times. True the spot was not continuously visible (or, if so, must have curiously eluded notice), and before 1878 it appears to have been much involved in the brighter material floating in the upper regions of the Jovian atmosphere. But the latitude of the spot, the general size and form of it, the rate of its rotation period, its colour, and the peculiar shouldering of the S.S.* equatorial belt, S. of its preceding and following ends, are all very significant features, and leave no reason to doubt that Gledhill's ellipse, first seen in 1869 November 14, was really the forerunner of the red spot, then perhaps in an incipient stage, and certainly not nearly so well developed as when Lord Rosse and Dr. Copeland rediscovered and followed it, on the last day of 1872 and during the early months of 1873, with the 6-foot reflector at Parsonstown.

1869 November 14 to 1870 March 29. The great southern ellipse was a fine object, and easily seen every clear night. It lay between the S.S. equatorial belt and the S. temperate belt. Its eastern end was the darkest part of it. It was followed up to 1870 March 29, and its transits or approximate positions relatively to the central meridian were noted on twenty-two nights. J. Gledhill ($9\frac{1}{3}$-inch refractor), *Astronomical Register*, vol. viii. p. 81, &c.

1870 January 5. "A great elliptical ring observed in the

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* This term is adopted for brevity to distinguish the dark belt forming the southern side of the southern equatorial double belt.

1898MNRAS..58..488D

planet's S. hemisphere and just S. of the equatorial belt. Its major axis to the minor axis is in its present projection as 1 to 1·51." It was about central at $8^h = 13^h\ 30^m$ G.M.T. A. M. Mayer (6-inch refractor), *Franklin Institute Journal*, 1870 February 7, and *Astronomical Register*, vol. viii. p. 169.

1871 December 1, $11^h\ 30^m$. S. of the S.S. equatorial belt, and near the W. edge of the disc, was a very large dark spot, and to the E. of this object lay the ellipse. Within it was seen a short, slightly curved dark line. A pretty dark band was in contact with the upper edge of the ellipse. A rough measure gave 15″ as the length of the longer diameter of this curious object. J. Gledhill (9⅓-inch refractor), *Astronomical Register*, vol. x. p. 11.

1872 January 5, 15^h; January 6, 10^h; and on February 2 and April 11, 16, and 28. A notable slanting streak was observed and drawn in the S. hemisphere; and following it was a well-defined elongated spot or preceding side of a belt lying S. of the great S. equatorial belt. E. B. Knobel (8½-inch reflector), *English Mechanic*, 1872 September 13.

*1872 January 6, 10^h to $10^h\ 45^m$. On the eastern part of the S. white zone, outlying the dark equatorial belt and just coming into view, was a dusky marking, its western end having an oval outline. H. Pratt (8½-inch reflector), *Astronomical Register*, vol. x. p. 43.

*1872 January 11 and 13. A striking feature is the belt-like streak which descends from the S., crossing the truncated end of the S.S. equatorial belt at a sharp angle, and reaching down to the S. equatorial belt. A large oval spot follows the slant belt. J. Birmingham (4½-inch refractor), *Astronomical Register*, vol. x. p. 42.

1872 February 2, 7^h. The sloping band is well seen, and to the east there is a dark and very broad cloud-like mass. J. Gledhill (9⅓-inch refractor), *Astronomical Register*, vol. x. p. 68.

1872 February 2, $7^h\ 46^m$. The S. temperate belt dips to N., and following it in about same latitude there is a renewal of the belt in an intensified form. F. Terby (3½-inch refractor), *Bulletin de l'Acad. R. de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.

1872 March 17. The slant streak now appears to extend to the dark region about the S. pole. In the angular space between it and the S.S. equatorial belt, and reaching

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* Two well-executed sketches of the appearances referred to by Birmingham and Pratt may be seen in *Astronomical Register*, 1872 February. The oval spot presents a very striking resemblance to the red spot of later years. It is to be regretted that Mr. Birmingham did not give the exact times of his observations on Jan. 11, 13, or March 17.

1898MNRAS..58..488D

quite across, is a large black spot, and under the spot a bright gap seems cut out of the S.S. equatorial belt. J. Birmingham ($4\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 94.

*1872 May 5, 9^{h} 15^{m}. A coloured sketch of *Jupiter* at this time shows a white slanting band as about central, while following it is a large dark mass. J. Browning (12-inch reflector), *Monthly Notices*, vol. xxxii. p. 322.

1872 December 31 to 1873 April 10. Of all the features presented to our view during the opposition of 1873 probably the most remarkable was the great break in the southern side of the equatorial belt in long. 260°. . . . Following and filling up this break was a brick-red area that was seen most fully on February 6. . . . The red region may extend over some 30° of longitude, reaching from 250° to 280°; its following end was well seen on March 22. The red area was also seen on 1872 December 31, 1873 January 17 and 22, February 8, March 7, and April 10. Lord Rosse and Dr. Copeland (6-foot reflector), *Monthly Notices*, vol. xxxiv. p. 243.

1873 April 20 and May 11. Two sketches of *Jupiter* exhibit the dip in the S.S. equatorial belt and a dusky mark coming into view on the E. limb. E. B. Knobel ($8\frac{1}{2}$-inch reflector). *Monthly Notices*, vol. xxxiii. p. 476.

1876 June 2, 0^{h} 35^{m} G.M.T. The red spot was frequently seen in 1876, and many drawings of it were made at the Sydney Observatory. The distance from the S. pole of *Jupiter* to the dark belt on the N. border of the spot was $15''\cdot54$, and in 1880 the same space was measured as $15''\cdot94$, so no change occurred in the latitude. In 1876 the *p* end of the spot was round and the *f* end pointed, while in 1873, according to Rosse and Copeland's drawings, the *p* end was pointed and the *f* end round. A sketch of the planet on June 2 at Sydney represents the red spot just entered on east limb. The spot was first seen separated from the belts on 1878 July 8; it was then a difficult object to see, but its form and dimensions were similar to that observed in 1876, and the observer was

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* The objects depicted by Browning are identical with those alluded to by Knobel, Birmingham, Pratt, Gledhill, and Terby in the previous winter months.

The slanting streak seems to have almost monopolised the attention of observers at this period, while the dark oval mass following it was not much regarded, though really of far greater significance, for it appears to have been undoubtedly the forerunner of the red spot.

The curved dark line seen in the interior of the ellipse by Mr. Gledhill on 1871 December 1 seems to have been preparatory to the filling up of that object with dark material. When it was observed by Knobel on 1872 January 5 and 6 and February 2, by Pratt on January 6, by Birmingham on January 11 and 13, and by Gledhill on February 2 it simply appeared as a dark elliptical mass.

1898MNRAS..58..488D

not long in recognising it as an old friend that he had frequently seen. H. C. Russell (11½-inch refractor), *Proceedings of the Royal Society of New South Wales*, vol. xiv. pp. 63–75.

1876 June 20, 7^h 30^m G.M.T. The spot was drawn just passing off the west limb. It was a dark and definite object with distinctly oval outline. T. Bredichin, *Annales de l'Observatoire de Moscou*, vol. iii. 1877.

Great Red Spot on Jupiter. Rotation Period 1869 *Nov.* 14 *to* 1898 *July* 30.

Observers.	Dates of the Observations.	h	m	Interval. d	h	m	Rotations.	Corrected Rotation Period. h	m	s	Daily Rate. °
J. Gledhill	1869 Nov. 14	10	50								
				1,209	1	10	2.923	9	55	34·4	870·42
Lord Rosse and Dr. Copeland	1873 Mar. 7	12	0								
				1,182	13	20	2,859	9	55	34·1	870·43
H. C. Russell	1876 June 2	1	20								
				852	11	9	2,061	9	55	33·4	870·45
L. Trouvelot	1878 Oct. 2	12	29								
				725	22	29	1,755	9	55	34·2	870·43
F. C. Dennett, W. F. Denning	* 1880 Sept. 27	10	58								
				1,164	1	43	2,814	9	55	37·3	870·35
W. F. Denning	1883 Dec. 5	12	41								
				1,108	6	44	2,679	9	55	39·6	870·30
” ”	1886 Dec. 17	19	25								
				1,074	8	29	2.597	9	55	40·2	870·28
” ”	1889 Nov. 26	3	54								
				1,174	2	21	2,838	9	55	40·7	870·27
” ”	1893 Feb. 12	6	15								
				1,093	0	34	2,642	9	55	41·0	870·26
” ”	1896 Feb. 10	6	49								
				901	1	40	2,178	9	55	41·7	870·24
” ”	1898 July 30	8	29								
J. Gledhill	1869 Nov. 14	10	50								
				10,484	21	39	25,346	9	55	37·8	870·34
W. F. Denning.	1898 July 30	8	29								

By selecting other observations in lieu of those utilised in the preceding table, it will be found that the periods deduced from them will be in very fair agreement. Thus, comparing an observation by A. M. Mayer on 1870 January 5, 13^h 30^m, with one by T. Bredichin on 1876 June 20, 6^h, I find the mean period 9^h 55^m 34^s·2 (5,700 rotations). Bredichin's observation, when combined with one by F. C. Dennett, 1878 September 28, 9^h 24^m, gives a mean period of 9^h 55^m 33^s·8. Other observations sufficiently prove that previously to the year 1878 the rate of motion of the spot was slightly increasing, but that a retardation set in afterwards. This retardation was very marked in the years 1880, 1881, 1882, and 1883. During this period the annual increase in the rotation period of the object amounted to one second, while during the 14 years from 1884 to the present time

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* This is a mean of the estimated times of the same transit taken by two observers. In subsequent years the observations are those made at Bristol.

1898MNRAS..58..488D

the average yearly increase has been only 0·2 second or one-fifth of a second.

A few of the objects offering a suggestive resemblance to the red spot, which were figured by observers in 1872 and other years, are certainly not to be identified with the latter. For instance, the dark oval marking drawn by Terby * on 1872 January 3 on the S.S. equatorial belt, and by Corder † in a similar position on 1872 March 13 and April 18, relate to one and the same formation, but it preceded the red spot by as nearly as possible three hours. Elliptical markings occasionally appear in the planet's S. hemisphere which are of more temporary character than, and probably somewhat different in nature to, the red spot. In 1885 a conspicuous red marking, known as the 'new red spot,' was seen on the S.S. equatorial belt, but it did not long remain visible.

In conclusion I give the annual rates of rotation exhibited by the spot. This table is only intended to show the general changes that have occurred; doubtless there have been well-marked minor variations causing a longitudinal oscillation of the object at comparatively short intervals. These, however, could only be satisfactorily traced by comparing a large number of very accurately observed transits. Mr. Marth had contemplated investigating the movement of the spot since 1879, but I fear the work was not completed at the time of his lamented decease.

Rotation Period in Successive Years of the Great Red Spot on Jupiter.

	h m 9 55 +	Comparisons with other Observers.			
	s				
1869	34·5				
1870	34·4				
1871	34·4				
1872	34·3				
1873	34·3	30^{s}·6	1872 Dec. 31–1873 April 10, Rosse and Copeland		
1874	34·2				
1875	34·0				
1876	33·7				
1877	33·4				
1878	33·7				
		s		s	
1879	34·1	34·0	1879, G. W. Hough	34·1	1878–80, Marth
		33·9	1879 July–Dec., H. Pratt	34·4	1879–80, Schmidt
1880	35·2	35·1	1880, H. Sternberg	35·3	1879–81, Schmidt.
		35·4	1880, G. W. Hough		

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* *Bulletin de l'Académie Royale de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.

† *Observatory*, 1882 January.

1898MNRAS..58..488D

	h m 9 55+ s	Comparisons with other Observers.	
1881	36·3	36·1 1881, H. Sternberg 36·4 1881, G. W. Hough	
1882	37·3	37·3 1882, H. Sternberg	
1883	38·2	38·1 1883, H. Sternberg 38·4 1883, G. W. Hough	1883–5 38·9, Marth
1884	39·0	39·2 1884, H. Sternberg 38·5 1883 Sept. 12–1884 June 11, G. W. Hough	
1885	39·6	40·1 1885, H. Sternberg 40·4 1884 Sept. 25–1885 June 29, G. W. Hough	
1886	39·9	40·1 1886, H. Sternberg 40·7 1886, C. A. Young 39·9 1886, G. W. Hough	
1887	40·1	40·6 1887, H. Sternberg 40·5 1887, A. S. Williams	
1888	40·2		
1889	40·4		
1890	40·5	39·8 1890 July–December, G. W. Hough	
1891	40·6	40·7 1890 December 8–1892 January, G. W. Hough	
1892	40·8		
1893	40·9		
1894	41·0	40·9 1893 December 20–1895 January 24, G. W. Hough	
1895	41·1		
1896	41·3	41·4 1896, G. W. Hough	
1897	41·6	42·4 1897 March–May, A. S. Williams	
1898	41·9	42·4 1898 March–June, T. E. R. Phillips	

Bristol: 1898 *September* 15.

Observations of Jupiter and Jupiter's Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1897–8. By Joseph Gledhill.

This paper comprises the following subdivisions :—

1. A description of the principal features seen on the disc of *Jupiter*.
2. Transits of red spot, dark spots, &c.
3. Measures of the position of the principal dark belts and spots.
4. Measures of the bright zones, dark spots, &c.
5. Observations of phenomena of *Jupiter's* satellites.